POLYMER MODIFICATION OF BITUMEN EXTRACTED FROM VARIABLE REFINERIES IN SAUDI ARABIA

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ABSTRACT

This study aimed to determine the effects of Styrene-Butadiene-Styrene (SBS) copolymer and other plastomers on the characteristics of bitumen materials produced in the Kingdom of Saudi Arabia (KSA). Bitumen used in this investigation was extracted from three Saudi oil refineries. Bitumen was mixed with different modifiers at different percentages to form Polymer Modified Bitumen (PMB). Three types of plastomers as well as SBS elastomer were used in this investigation.

Elasticity and other properties such as ductility and elastic recovery were measured and evaluated following the international standards. The effects of polymer on neat bitumen were determined using variable evaluation tools and under various testing conditions. Based on current study results, the PMB blend made with SBS showed better elastic behaviors compared to the those blends made with plastomers.

1 INTRODUCTION

Bitumen is a complex mixture of heavy hydrocarbons with different characteristics and properties. The composition of bitumen varies depending on the origin of crude oil. Table 1 shows the physical and chemical characteristics of bitumen (Rahimi and Gentzis, 2007). Polymer Modified Bitumen (PMB) has been increasingly used to enhance pavement performance. Many studies have confirmed the improvement of the pavement performance when using polymer modified bitumen (AASHTO, 1993; Raad et al., 1997; Zubeck et al., 2003). It has been proved that PMB is effective in reducing rutting and improving fatigue and thermal crack resistance (Yildirim, 2007; González, 2004).

There are two main categories of polymers that have been used widely for modifying bitumen (Yildirim, 2007). These polymers are thermoplastic elastomers and plastomers. Styrene-Butadiene-Styrene (SBS) is an example of the thermoplastic elastomers. Examples of plastomers are polyethylene (PE), polypropylene (PP) and ethylene-vinyl acetate (EVA).

Superpave mix design that was developed through the Strategic Highway Research Program (SHRP) is becoming the major asphalt mix design method in the KSA. Tests conducted on modified binders obtained by mixing various types of polymers with base asphalts showed that asphalt source and polymer type have significant effects on resulted modified binders. Such results can be used as guidelines in the production of PMB (Aazam, 2007).

The objective of this study is to evaluate the effects of SBS copolymer and other plastomers on the characteristics of PMB produced in the KSA. Three different plastomers as well as SBS elastomer were used as modifiers. The samples of plastomers are identified as: Polymer A, Polymer B and Polymer C. Original bitumen samples were obtained from different refineries including Ras Tanura, Riyadh and Yanbu.

Table 1 Physical and Chemical Characteristics of Bitumen

Penetration at 25 °C, 1/10mm	150-200	180-220	80-100
Ring & Ball temperature, °C	40	39	47
Penetration index	-0.52	-0.18	-0.65
Chemical composition (ASTM D-4124)			
Asphaltenes, %	10	9	11
Polar-aromatics (resins), %	42	40	38
Naphtene-aromatics, %	39	43	45
Saturates, %	8	8	6
Chemical composition (latroscan)			
Asphaltenes, %	6	5	7
Aromatics, %	66	70	65
Polar comp., %	20	17	22
Saturates, %	8	8	6

2 EXPERIMENTAL WORK

The major goal of this study is to check the compatibility of Saudi bitumen to be mixed and modified with SBS and other plastomers and to forecast what the mixing conditions should be as well as the most appropriate neat bitumen to start with. The testing methodology which was pursued during this study consists of the following steps:

a. Analysis of bitumen composition by using the LATROSCAN instrumented Chromatography. Due to the complexity of bitumen, its characterization is made by grouping it into four generic fractions including;
   - Saturates are those components with lowest molecular weight, generally long chain paraffin and naphtenes.
   - Aromatics are compounds of medium molecular weight with aromatic ring structure.
   - Resins (Polar compounds) are substances with high molecular weight, which contain different heteroatoms within its structure.
   - Finally, asphaltenes are the heaviest of the components in bitumen. They operate as micelles (or solid phase), which are in suspension solvated by the resins. Results of Saudi bitumen composition are shown in Table 2.

b. Laboratory mixing of bitumen with selected polymers. Different grades of SBS and plastomers at different percentages were used. According to early experience in the KSA, 3, 4 and 5% (by total PMB weight) of polymers were considered and blended with neat bitumen to produce PMB. Based on added polymer, mixing process was customized in terms of mixing temperature, time, and blending shear requirements.

c. PMB were tested following the international standards for ductility, elastic recovery, force ductility (cohesion), elastic modulus and Frass breaking point.

Table 2 Saudi Bitumen Composition

Type of Bitumen	Ras Tanura	Riyadh	Yanbu
Penetration 25 ºC, 1/10 mm	70	70	62
Saturates %	6.9	5.3	3.3
Aromatics %	62.0	64.6	67.6
Resins %	23.0	20.9	22.0
Asphaltenes %	8.0	9.2	7.2

The PMB was tested at 5 and 25 ºC. PMB consistency parameters were tested including both penetration at 25 ºC and viscosity at 160 ºC. Also, storing stability (at 180 ºC for 3 days) and durability (by means of measuring the resistance against hardening) were evaluated.

3 RESULTS AND DISCUSSION

Composition and characteristics of neat bitumen obtained from various refineries are shown in Table 2. Results showed that the aromatic content was at appropriate level (above 60 %) for all tested bitumen. The asphaltene content is slightly higher than the standard level (7 %). However, the neat bitumen from those refineries is appropriate for modification with SBS and plastomers. The neat bitumen from Ras Tanura and Riyadh showed similar characteristics. Based on obtained results, Yanbu refinery neat bitumen seems to be more compatible with polymers due to its higher aromatic content (Figure 1).

Elasticity is the top candidate for PMB characteristics. PMB with 4% SBS proved higher values for elastic recovery and ductility. Plastomers (Polymers A, B and C) didn't show good elasticity in terms of elastic recovery and ductility. Figure 1 shows the ductility results. PMB using neat bitumen extracted from Yanbu refinery showed better elasticity and storing stability compared to those neat bitumen obtained from Ras Tanura and Riyadh refineries. Higher aromatic content of Yabnu bitumen makes the blending with modifiers more efficient.

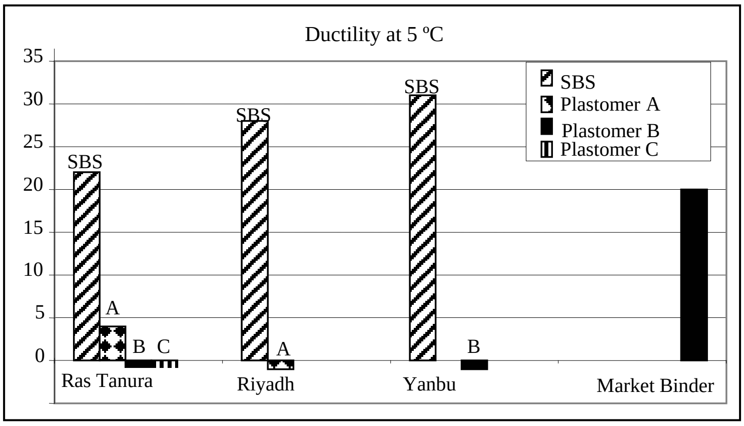

Figure 1 Ductility Values for various PMB

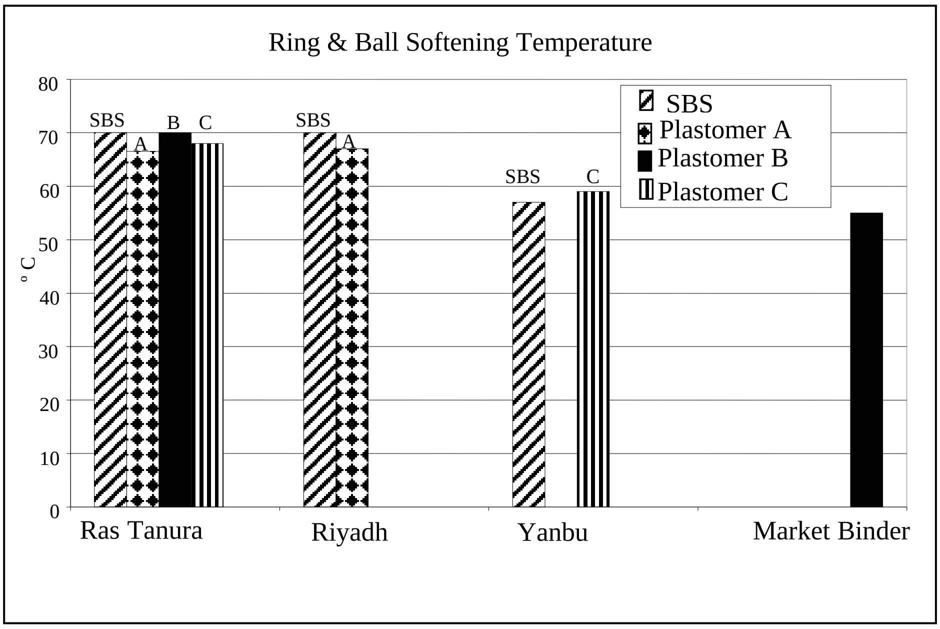

Figure 2 the Ring and Ball Softening Point for Various PMB

Ductility tests were conducted at temperatures of 5 and 25 ºC. Viscous PMB (modified with Plastomers A, B, and C) showed early failure with very little elastic recovery. Elastic recovery is a major concern regarding pavement rutting and fatigue cracking characterizations.

The Ring and Ball (R&B) softening point showed similar results for all tested PMB (Figure 2). It appears that Plastometrs molecular weight affects the measured R&B temperature. Higher Plastomer molecular weight (Plastomer B) showed higher R&B temperature while Plastomer A (low molecular weight) proved lower R&B temperature.

Figure 3 shows the PMB measured viscosity at 160 ^{o}C. PMB modified with Plastomers (A, B, and C) proved lower viscosity than that for PMB modified with SBS. Plastomers heavy molecular weights appear to be the reason for lower viscosity measurements. The Frass Flexibility Breaking Point (FFBP) is a standard European test to evaluate the cracking resistance of bituminous binders at low temperature. In this test, a thin PMB sample is cooled down and stressed. The FFBP is the recorded temperature where the first crack appears within the tested sample. Figure 4 shows the FFBP results of tested PMB.

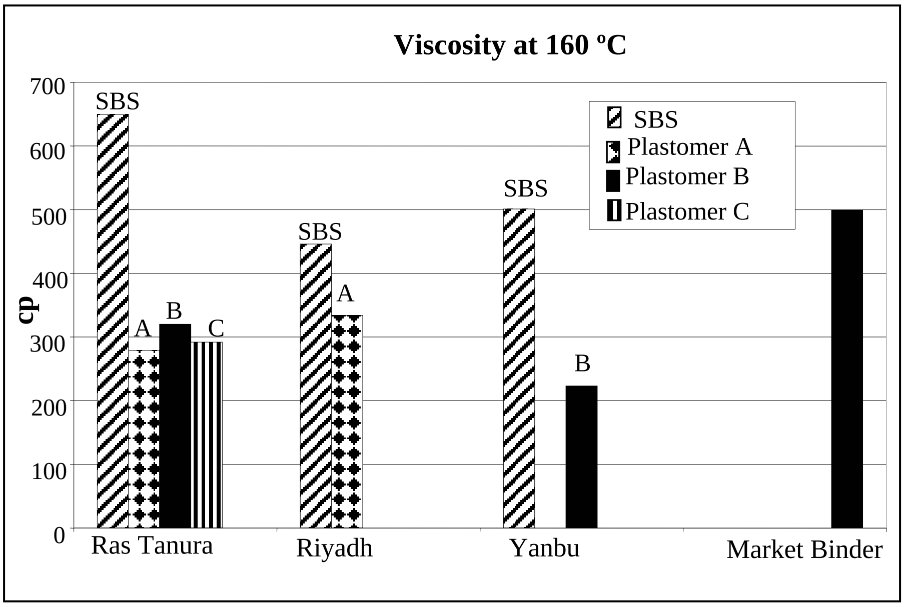

Figure 3 Viscosity changes versus different modified Saudi bitumen

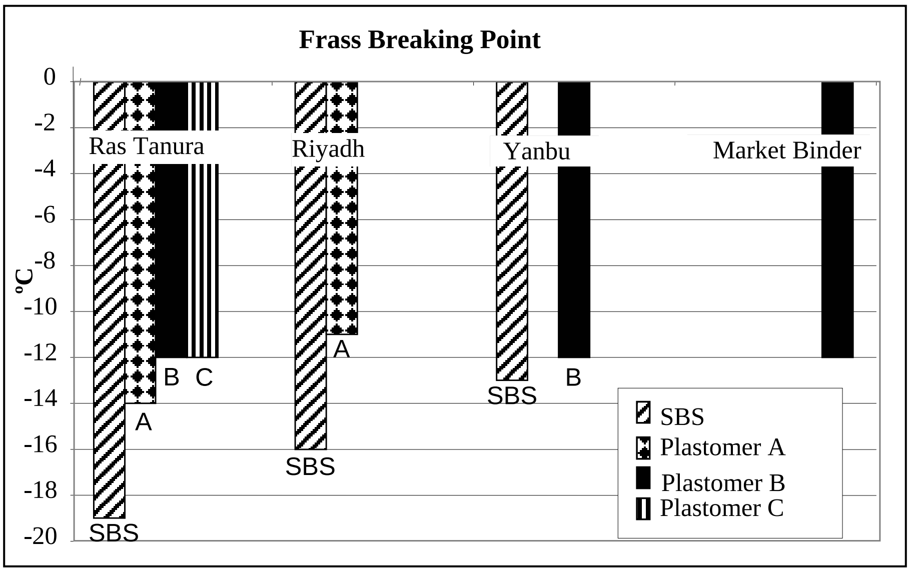

Figure 4 FFBP results of tested PMB

4 CONCLUSIONS

Neat bitumen obtained from various refineries in KSA was modified and investigated. Characterises and composition of bitumen obtained from both Ras Tanura and Riyadh refineries are similar. Bitumen obtained from Yanbu refinery contains more aromatics. One elastomer (Styrene-Butadiene-Styrene) and other three plastomers (polyethylene, polypropylene, and ethylene-vinyl acetate) were blended with neat bitumen to produce PMB. Bitumen obtained from Ras Tanura, Riyadh and Yanbu refineries were all pronounced for modification with SBS.

PMB modified with SBS showed better elastic properties than those PMB modified with plastomers (polymers A, B and C). PMB elasticity is essential to minimize flexible pavement fatigue cracking and permanent deformation, especially in high temperature environment. PMB using SBS proved higher ductility and elastic recover than those PMB modified with plastomers. No significant differences in R&B temperature for tested PMB were observed, for all neat bitumen extracted from Ras Tanura, Riyadh and Yanbu refineries. PMB measured viscosity for PMB modified with SBS was higher than those for PMB modified with plastomers due to the differences in molecular weights. FFBP temperatures for PMB made with SBS were lower than those of PMB made by adding plastomers.

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